Robert Bell

The Ore Deposits of Rossland

British Columbia
Canada

By

Edmund B. Kirby, E.M.
Rossland, B.C.

Compliments of
The Rossland Board of Trade

Journal of the Canadian Mining Institute, Vol. VII.

THE ORE DEPOSITS OF ROSSLAND, BRITISH COLUMBIA.

BY EDMUND B. KIRBY, E.M., Rossland, B.C.

(Illustrated by four Maps.)

Toronto Meeting, March, 1904.

The Rossland mining district began active production in 1894. Its total yield up to January 1st, 1904, is 1,620,540 tons of smelting ore, containing about $26,000,000 gross value, or $16.00 per ton in gold, silver and copper.

This tonnage was derived from the following mines:

	Approximate Tonnage
Le Roi	974,785
War Eagle	240,455
Centre Star	229,648
Le Roi No. 2 (Josie & No. 1 Mines)	115,007
Iron Mask	17,655
Rossland Great Western-Nickel Plate	12,331
Columbia-Kootenay	7,790
Velvet	5,416
Jumbo	4,395
Giant	4,344
I.X.L.	2,900
Miscellaneous	2,447
Evening Star	1,500
Spitzee	900
Monte Cristo	400
White Bear	302
Homestake	140
Virginia	100
Portland	25
	1,620,540 tons, Est. Val. $25,816,342. Average. $16.00.

The ore is transported to the Columbia river over two competing lines of railway, and supplies extensive smelting works at the town of Trail and at the town of Northport. These towns together with a population of about 6,000 in Rossland, are thus supported by the mines.

GEOLOGICAL POSITION.

The geological position of these ore deposits is shown by map I, which is a slightly modified copy of a map by the Geological Survey of Canada, from studies by Mr. R. G. McConnell. The elongated oval area of gabbro is surrounded by a border of varying width of augite and uralite porphyrites and fine grained green diabases. The transition from the gabbro to the porphyrites is not well defined, and they are both from the same magma. Beyond the above border come alternating series of porphyrites, tuffs and slates, and beyond these are agglomerates.

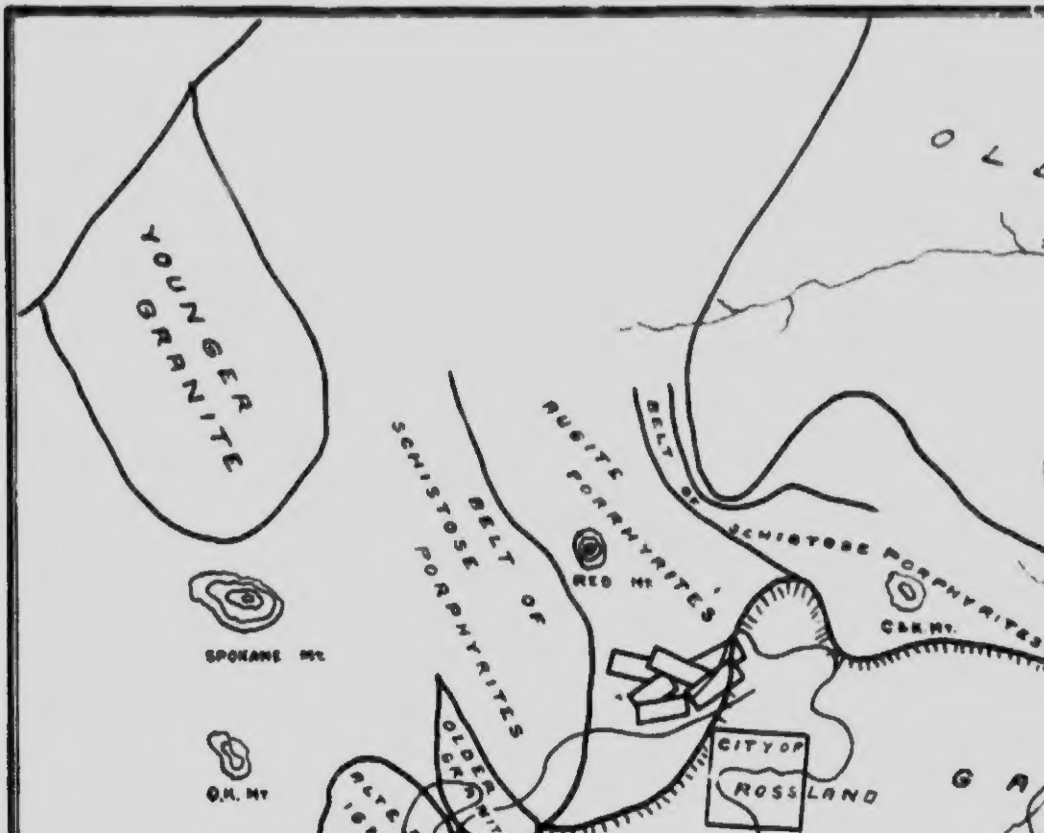
The basic coarse crystalline and plutonic gabbro thus surrounded by borders which become more acidic and finely crystalline, and finally pass into volcanic breccia and tuffs, indicates an ancient volcano centre. The gabbro area is the main plug or neck of lava crystallized at great depths and exposed by deep erosion. Its great age is indicated by this erosion and by the numerous alterations in the rock structure and in the rock minerals.

The active mining has been carried on not within the gabbro area but outside of it and in the porphyrites surrounding its western end. The principal mines are all included in the small group of claims shown near the edge of the gabbro and located on the flank of Red Mountain above the town of Rossland. Map No. II is a horizontal section through this group of claims at the approximate elevation of 3,530 feet above sea level. It shows the structure details exposed by the workings of the Le Roi, Centre Star, War Eagle, Josie, Number One and Iron Mask mines. These mines aggregate some 20 miles of total workings, and the principal depths attained are those of the War Eagle, 1,615 feet measured on the vein; the Le Roi, 1,361 feet, and the Centre Star, 1,289 feet.

On the west of these claims there is a belt of fine grained eruptives, probably porphyrites, which are in a schistose condition; having been so plated by pressure as to frequently resemble shale.

COUNTRY ROCK OF MINES.

Within the area of the claims the prevailing rock is evidently



YOUNGER GRANITE
BELT OF SCHISTOSE PORPHYRITES
AUGITE PORPHYRITES
RED MT
BELT OF SCHISTOSE PORPHYRITES
SPOKANE MT
O.K. MT
OLDER GRANITE
ALTERED IGNEOUS BASIC ROCKS
CITY OF ROSSLAND
C&K MT.
DEER PARK MT
RED MOUNTAIN R.R.
TO NORTHPORT
GENERAL GEOLOGY
ROSSLAND MINING
SLIGHTLY MODIFIED
MAP OF GEOL. SURVEY
EDMUND B.
SCALE OF MILES


OLDER
Stony Creek
GRANITE
COLUMBIA
RIVER
RAILWAY
AND WESTERN
COLUMBIA
CITY OF TRAIL
ORPHYRITES
Trail Creek
GABBROS
PALAEOZOIC VOLCAN ROCKS
[EFFUSIVE AND FRAGMENTAL]
EOLOGY OF
INING DISTRICT
ODIFIED FROM
RVEY OF CANADA
B. KIRBY
F MILES

MAP No 1

al
ra
of
pı
it
ti
o
t
n
c
l
l
t
l
c

all from the same magma, but shows innumerable variations in rate of cooling and degree of metamorphism. It is mainly composed of plagioclase feldspars and pyroxene, generally in about equal proportions, but towards the gabbro area, bodies of pure pyroxenite are occasionally encountered. There is usually a small proportion of orthoclase feldspar and sometimes hornblende, and some observers have noted the fact that these appear more frequently towards the west. The rock appears to be holocrystalline and more or less porphyritic. The crystals may be either microscopic or as large as, say, five mm., while one or two mm. is a common limit. The feldspars are more or less altered to a turbid or porcelain-like appearance, while the pyroxenes are partially transformed to fibrous minerals of the uralite group. In strongly altered places, and especially within the veins, the rock is frequently colored brown from microscopic crystals of secondary biotite.

Although varying considerably in different places, specimens of this rock have generally been determined by microscopical observers as augite porphyrite, and it certainly belongs to the gabbro group, differing from the central area mainly in relative time and rate of cooling. Broadly speaking, the size of crystals tends to increase towards that area, and coarse crystalline masses are more frequently encountered; while in the other direction the structure becomes more fine grained.

DIKES.

This country rock is cut by innumerable dikes which require detailed comparison and determination by the microscope. Generally speaking they appear to be mica traps (perhaps kersantites) and altered basalts (perhaps melaphyre). The latter are often greatly decomposed.

The general direction of the parallel fractures has been north 10° W. with dips which are either vertical or very steep to the east. Their detailed fluctuations in strike and dip and the way in which they branch, unite and re-branch are clearly shown by the map. As explained hereafter, they probably belong to at least two periods, one before and the other after the ore deposition. Occasional belts of special crystallization in the country rock

indicate dikes of an earlier date, which have since become cemented with the country rock and jointed to correspond with it. These have not been mapped.

THE VEINS.

These are shear zone fissures consisting of a series of parallel platings of the rock produced by shearing under high compression. In the Centre Star-Le Roi vein, in which the shear zone is most typically developed, this series of platings is 20 to 40 feet wide and dips about 70° to the northwest. The Josie vein is parallel; but the Centre Star north vein, the War Eagle and Iron Mask veins are branches from the Centre Star-Le Roi vein. Their positions and dips are shown upon the maps. The three latter veins also exhibit many of the characteristics of ordinary fissures and thus appear to have been formed under a less degree of compressive shear.

The ore consists of country rock more or less replaced or impregnated by pyrrhotite, accompanied in places by small proportions of chalcopyrite, pyrite, arsenopyrite and quartz. The pyrrhotite when it occurs by itself even in solid masses carries but little gold, say, from 50 cents to $3.00 per ton. The chalcopyrite is the principal carrier of gold, and ore of commercial value occurs only in those localities where chalcopyrite, pyrite and arsenopyrite have been deposited with the pyrrhotite. The manner in which these minerals occur within the interstices of the pyrrhotite, and the fact that continuous masses of pyrrhotite ore are impregnated in some places and barren in others, proves the later deposition of these valuable minerals. They have been introduced after most of the pyrrhotite was in place, although occasional occurrences of chalcopyrite and pyrrhotite in quartz point to the possibility of some contemporaneous deposition. The change from one deposition to another was probably gradual. A small proportion of the gold in the ore is native in the form of small grains and scales. The fact that oxidation extends only a few feet below the surface, while the proportion of metallics seems to average much the same even in ore shipments from the lower levels, suggests original deposition in this form. No data have

been collected, however, to indicate whether it was contemporaneous with the pyrrhotite formation.

The average proportions of gold, silver, copper and total sulphides in a grade of, say, $16.00 full assay value are as follows:

Metal or Mineral.	Average Centre Star Ore.	Average War Eagle Ore, representing also Ore of Number One, Josie, Le Roi.
Gold (oz.)	0.63	0.54
Silver (oz.)	0.45	1.10
Copper (per cent.)	1.17	1.88
Sulphide Minerals (per cent.)	25.7	23.2

In various places the pyrrhotite seems to be accompanied by a little nickel and cobalt, specimen analyses ranging from 0.13 to 0.65 per cent. nickel, and from a trace to 0.59 per cent. cobalt.

FAULTS.

These have an average direction which corresponds to the dike system, with dips ranging from vertical to 50° easterly. Out of the great number of fractures studied and surveyed only the principal faults have been plotted, *i.e.*, those fractures which appear to have affected the veins by well defined displacements or by acting as barriers to mineral solutions. The map gives only a partial idea of the way the main faults branch in strike and in dip, and of the numerous minor interlacing fractures which connect them. In certain localities it will be seen that the ground is hopelessly shattered.

The faults are frequently not plainly marked, having no clay filling and at most only a small thickness of comminuted material. They frequently consist of a zone or series of close fractures, some of which are better marked than the others, and these fracture planes often interweave in such a manner that local measurements of their strike and dip are deceptive, and these can be determined only by comparison with other workings. As

a general rule, the faults appear to have been too tightly compressed to give access to mineral solutions, and those existing during the deposition period have therefore tended to act as barriers to the flow of these solutions.

Since individual faults often cross dikes at sharp angles in strike and dip, a fault frequently breaks along a dike for considerable distances. Hence in many cases of vein displacement it is impossible to say how much of the total amount has been due to the dike fracture, and how much to subsequent fault fractures accompanying it. In most cases where dikes are not accompanied by plainly marked fracture planes the displacement is so small as to indicate that the fault system and not the dike has probably been responsible for most of the shifting.

The sharp angles at which the faults cut the War Eagle vein have tended to produce overlaps of the vein, which is most clearly illustrated by its intersections with fault (E) on upper levels.

The Josie and the Centre Star-Le Roi veins being crossed more squarely by the fault system, afford the best indications of its effects. The Josie dike, or more probably an undetermined fault accompanying this dike, have caused a displacement, which is indicated in the Josie and Number One vein to be a north throw going east. Proceeding east from fault to fault they are found to have the same throw up the faults (I and J) at the junction of the Le Roi-Centre Star territory, after which the steps occur in the other direction, with a throw to the south. On reaching fault (Q) a north throw is again encountered, and the steps to fault (T) are then south, north, north. The large scale reversal of stepping in both directions from faults (I and J) indicates a lifting of the blocks from this centre, the possibility of which is borne out by various connections of the fractures between faults (H) and (K), indicated in lower workings. As explained hereafter, much of the faulting occurred after the ore deposition and also at a later date than the dike formation.

DISTRIBUTION OF ORE AND ORE SHOOTS.

The pyrrhotite mineralization has been very abundantly distributed through the larger veins, but the subsequent deposition

of gold and copper bearing minerals has been more localized, occurring in the more favorable places. The bodies of valuable ore thus formed are sometimes lenses, tapering out at the edges, and sometimes blocks terminating against faults or dikes. These ore bodies are found distributed within more limited portions of the vein area, which in the practical sense thus constitute the ore shoots, and indicate those portions of the area to which the gold and copper bearing solutions had the best access. The shoots are upon such a large scale and of such irregular form that their shape and limits have been developed very slowly, and the largest and best defined up to the present date are those of the War Eagle, Centre Star and Le Roi mines.

The War Eagle shoot has a dimension of 300 to 450 feet along the vein, and an almost perpendicular trend upon its plane. It is so located that its median line roughly coincides with the line of the main shaft.

The Centre Star main shoot is located in the space between the shaft and the Le Roi end line, and appears to have a dimension of 300 to 500 feet along the vein, with a steep trend to the east. The Centre Star east ore shoot is several hundred feet east of the shaft, but has not yet been sufficiently developed to determine its length along the vein or its trend, although the latter now appears to be either perpendicular or very steep towards the east.

The Le Roi ore shoot on the 350 foot level stands near the east end of the claim, as shown on the map, and descends perpendicularly, then assuming a westward trend. A little below the plane of the map it stretches out so as to include the entire distance between the Josie dike and fault (I), as illustrated by map III, of the Le Roi 700-foot level. The structure of the shoots and of the pay ore bodies within these shoots everywhere points to the conclusion that their location and shape are due entirely to the accidental conditions directing the upward flow of the mineral bearing solutions.

The marked difference between the proportions of gold, silver and copper in the Centre Star ore shoots and those of the other mines suggest that the solutions in the Centre Star came from

a different region than those which furnished the other deposits. The fact that the Centre Star was somewhat nearer to the volcanic centre than the others, and that its ore shoots trend in that direction, may account for this.

These shear zone fissures, more or less shattered by repeated movements, have afforded permeable channels for the ascending mineral solutions, which have penetrated and decomposed the country rock, replacing its rock minerals wholly or partially by metallic minerals. In places the entire width of the shear zone has thus been transformed into ore, while in other places the mineralization has been narrow. The solutions have frequently jumped across from one set of plating fissures to another, shifting the pay streak from the hanging to the foot side, or to intermediate positions, as the case may be. In the Centre Star-Le Roi vein the foot wall fissure is the one which is the most regular and distinct, and is marked by a vein of small interlacing calcite seams, which has been found a very reliable indicator of the position of the vein. As a rule, the heaviest ore deposition has taken place near this foot wall, and mineralization extends to irregular distances on the hanging side, gradually fading into the country rock. In the War Eagle vein the hanging wall is generally the most distinct and best mineralized, with irregular extension into the foot wall side.

While many of the dikes and faults merely occasion small displacements, with no effect upon the mineralization, a number of them evidently occurred before this mineralization was begun, or at least before its completion, and acting as partial barriers to the flow have so deflected the solutions as to greafly increase the deposition on one side, although they have not themselves been mineralized. Map IV of a portion of the War Eagle 6th level, illustrates the way in which solutions rising through the fractured ground, caused by a fork in the vein, have been stopped by a large dike, and were so deflected and accumulated in rising along its under side as to produce exceptionally large and rich ore bodies. In the Josie vein the tramway dike has in a similar way produced the Annie ore shoot below the plane of the map, and the Josie dike has had the same effect upon the Le Roi and the

Black Bear veins (see map III). In both these veins the solutions towards the west end seem to have been more or less confined to the space between the Josie dike and the partial barrier afforded by fault (D). Between (D and E) the ore bodies are smaller and less frequent. The principal channel for solutions has been between faults (E) and (I), where large masses of ore have formed, reaching widths of 100 feet up against fault (E). The same phenomena are repeated throughout the Centre Star ground, as exhibited by map II, which everywhere shows the tendency of such mechanical barriers to deflect or accumulate the solutions. In the Centre Star it will be noticed that the principal channel has been that portion of the vein between fault (K) and fault (Q). Fault (K), however, notwithstanding its large displacement, has for some reason been an imperfect barrier. In the lower levels heavy deposition has occurred on both sides of it, while on the second level, shown on the map, it has been mainly on the east side, and at this horizon is also accompanied by a deposition of ore along the plane of the fault. This is rather exceptional, and, in fact, is the most clearly marked case of deposition within fault planes. In the few other instances there is some doubt as to whether the material is not dragged ore or an original vein. As a rule, the faults do not appear to have been very accessible to the solutions.

The numerous instances of displacements by faults and dikes where the severed portions of the vein on each side are alike, prove that some of the dikes and some of the faulting occurred after the ore formation. If the dikes were studied in detail and classified they would probably be found to belong to two or more different periods, some of which were later than the deposits. As to faults, the facts observed accord fully with what is known of dynamic action during the long period while volcanic activity is expiring. Shocks and movements occur repeatedly at increasing intervals. Early fractures afford planes of weakness which would not only be kept open by the repeated movements but would be multiplied and extended by branches and interlacing fissures. Such action probably continued long after the ore de-

position and also after the dike formation, since these are found to be cut by faults.

It is very noticeable that the later solutions introducing the gold and copper bearing minerals with quartz have, as a rule, followed the pyrrhotite deposition, and in this locality do not seem to have sought or found new permeable channels in the rock where these minerals might deposit by themselves. On the contrary, they seem to have been unmistakably restricted to the ground already impregnated with pyrrhotite, and the greatest enrichment has, as a rule, occurred where the previous pyrrhotite deposition was most extensive.

There seems no reason to believe that the pyrrhotite had chemically any more influence on the subsequent deposition than ordinary country rock would have. It may have been that the friable pyrrhotite ore presented such local weaknesses as to become especially shattered by the further repeated movements, and thus afforded the most permeable channels. What probably occurred, however, was that there was one continuous flow which gradually changed in chemical contents and conditions of deposition. The altered solutions at the time of the later deposition merely followed the channels of flow which were already established, possibly modified more or less by a refracture or brecciation of the pyrrhotite ore.

CONCLUSIONS.

The conclusions derived from a study of these deposits are as follows:

(1) The pyrrhotite was deposited from aqueous mineral solutions ascending through the more fractured and permeable portions of the shear zone fissures.

(2) The gold bearing chalcopyrite, pyrite and arsenopyrite with quartz were deposited later from the same flow rising within the same channels but restricted to those portions of the channels which still remained unfilled, or which were re-opened by further fracturing of the friable pyrrhotite ore.

(3) The main faults and some of the dikes existed before the formation of pyrrhotite began, or at least before its principal deposition.

(4) Their intersections with the vein planes made barriers which more or less directed the flow, accumulated the solutions, and determined the position of the main ore bodies.

(5) After the ore formation more dikes appeared. Faulting was repeated intermittently, continuing probably up to recent times, and the early fractures were kept alive.

The writer is well aware that the origin of pyrrhotite is still in dispute by eminent authorities, but believes that a study of the Rossland deposits must remove any remaining uncertainties as to this question. All observations, from the occurrences of the pyrrhotite as mineral replacements, veinlets and films in the rock to the effect of dikes and fractures in massing its formation, point to deposition from mineral solutions. In these deposits at least, it is impossible to even consider "direct igneous origin" or "magmatic segregation," and no evidence has been found to suggest any difference between their origin and that of ore deposits of galena, pyrites or other minerals whose genesis is now established.

The evidence does show, however, that the conditions necessary for pyrrhotite deposition prevailed at an earlier time than those required for chalcopyrite, pyrite, arsenopyrite and quartz. It is well understood that during the period while heated waters are ascending in the vicinity of cooling eruptive masses the chemical contents of the solutions slowly change and so do the conditions of deposition. For the same flow to first yield pyrrhotite and then so alter as to produce the other minerals is no more exceptional than the well-known successive deposition in veins of the more common minerals. It may be that the only difference between their origin and that of pyrrhotite is that the latter requires exceptional depth, heat and pressure. The heat would be greatest during the earlier stages of circulation, and the great erosion noted by the Geological Survey indicates the prevalence of unusual depth and pressure at the time.

EFFECT OF STRUCTURE UPON MINING METHODS.

Map II illustrates the peculiar difficulties presented to exploration work within an ancient volcano. Every dike and every

zone of fissures constituting a fault creates a gap or blank in the formation and to these are added the gaps due to vein displacement. Systematic cross cutting aided by diamond drilling is necessary on account of these displacements, vein-branching, the variations of vein thickness and the shifting of ore from one set of planes to another. If carelessly placed a cross cut or drill hole encounters so many of these blanks as to afford no information, or what is worse, indecisive results. It is therefore very difficult to make such work efficient, and it calls for every resource of care and skill.

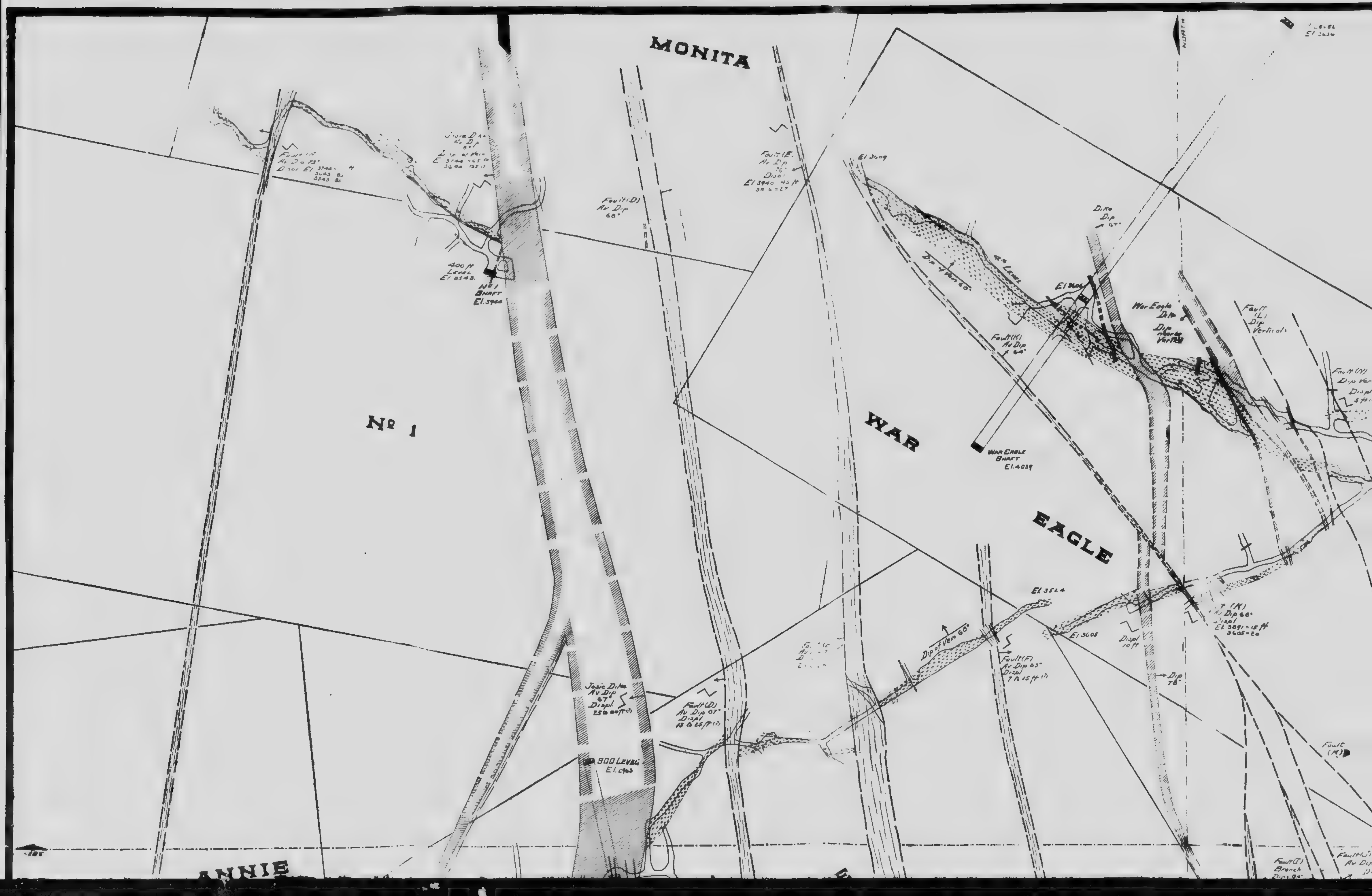
In the War Eagle and Centre Star mines structure details are carefully kept up, and it is endeavored so far as possible to make cross cutting effective, to avoid work within belts of dike systems or belts of shattered ground, and to direct the principal explorations to the main channels of flow.

ACKNOWLEDGMENTS.

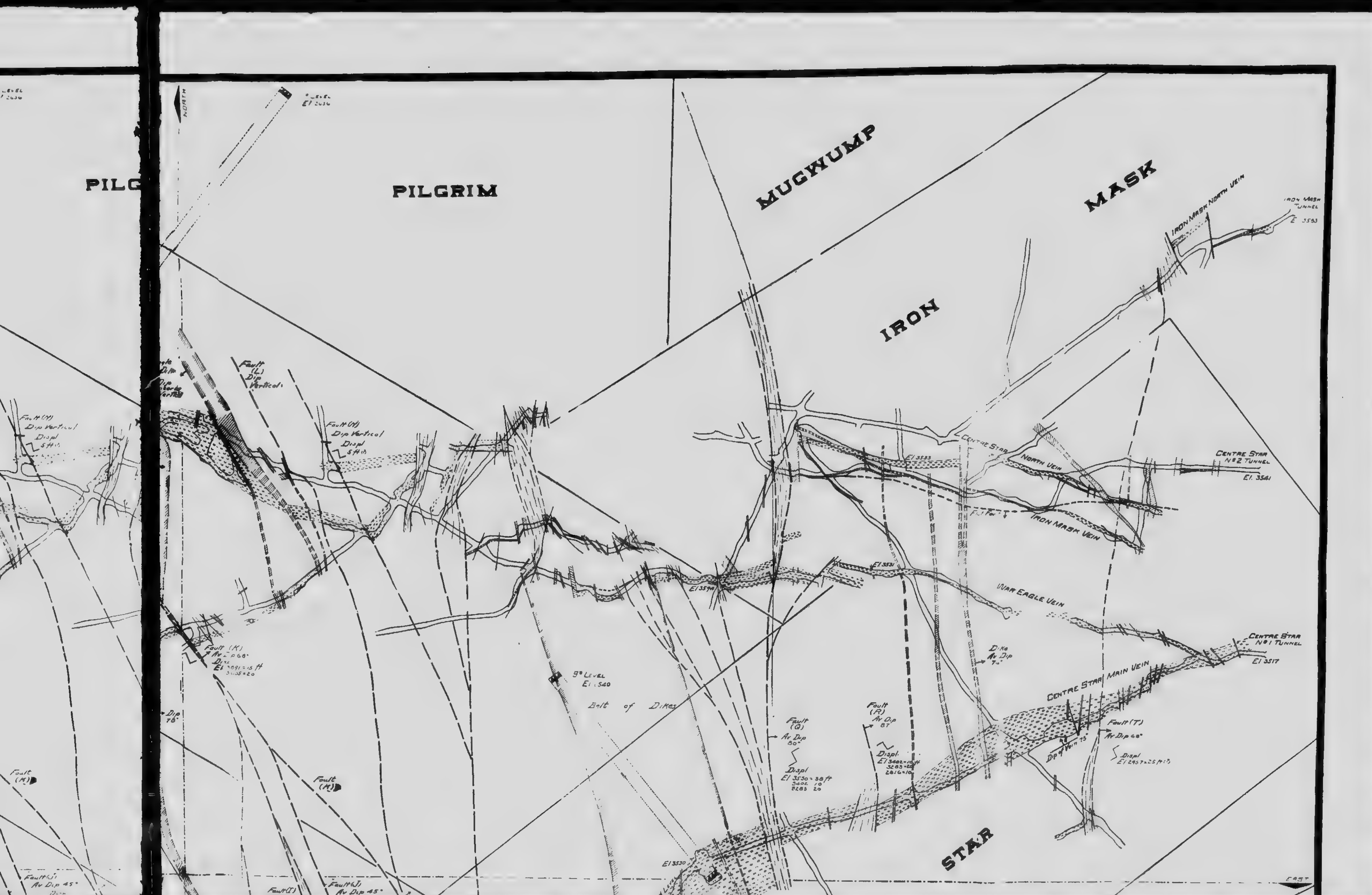
The structure details of the maps are by Mr. Carl R. Davis, E. M. Superintendent of the War Eagle and Centre Star mines, and Mr. Hugh Rose, A. B. Mining Engineer. The writer also desires to acknowledge the friendly assistance and courtesy extended to him by Mr. S. F. Parrish, Manager of the Le Roi Mining Co., Limited, and Mr. Wm. Thompson, Manager of the Rossland Kootenay Mining Co., Limited, and Mr. Paul S. Couldrey, Manager of the Le Roi No. 2 Mining Co., Limited, who have freely placed at his disposal all the data and information in their possession concerning the structure of these deposits.

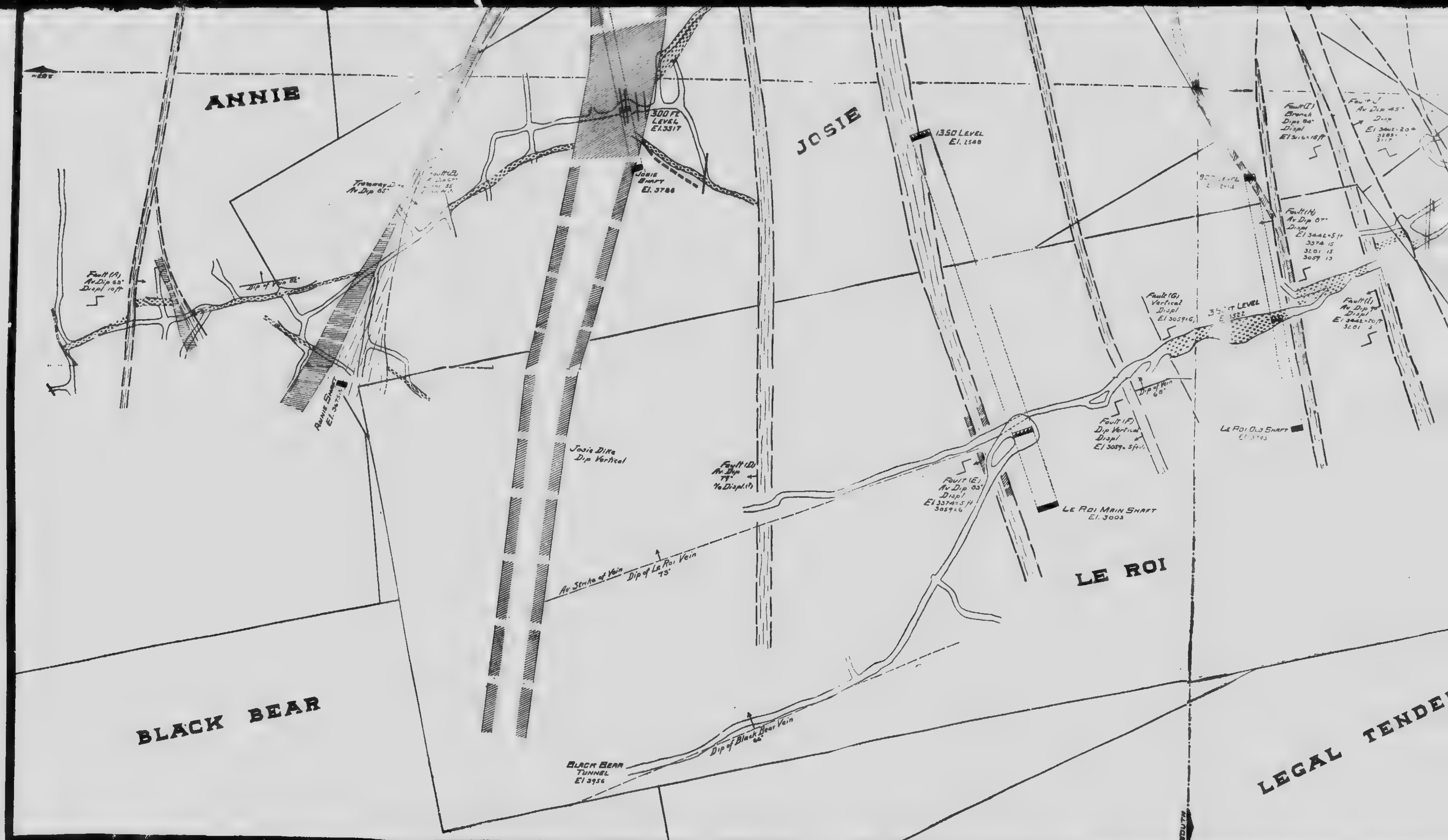
DISCUSSION.

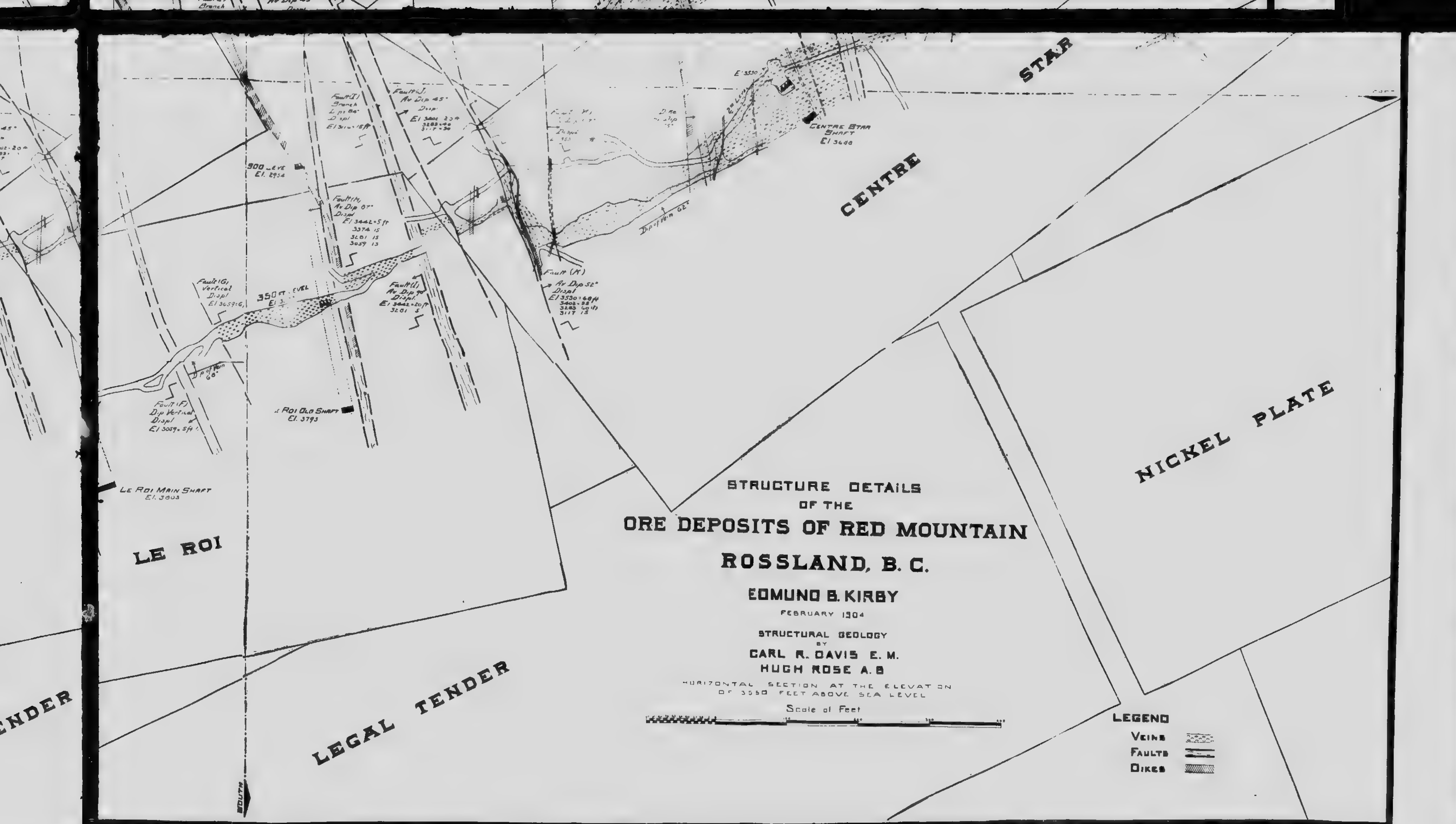
The President—Mr. Brock is so well acquainted with the district referred to in the paper that we were fortunate to have him here to read it for Mr. Kirby, and we are all indebted to him for it. I understand that arrangements have been made to ship some of the Rossland ores to the smelters of the Boundary Creek,



MONITA
Nº 1
WAR
EAGLE
ANNIE
NORTH
400 ft Level El. 3543
Nº 1 Shaft El. 3944
Fault (D) Av Dip 68°
War Eagle Shaft El. 4039
4th Level
Dip of Vein 60°
Fault (K) Av Dip 60°
War Eagle Dike
Fault (L) Dip Vertical
Dike Dip 67°
El 3524
El 3605
Dip of Vein 60°
Fault (F) Av Dip 83°
Josie Dike Av Dip 67°
Fault (D) Av Dip 67°
900 Level El. 2963
Dip 78°
Displ 10 ft
Fault (K)


PILGRIM
MUGWUMP
IRON
MASK
STAR
NORTH
IRON MASK NORTH VEIN
IRON MASK TUNNEL
CENTRE STAR NORTH VEIN
IRON MASK VEIN
CENTRE STAR No 2 TUNNEL
El. 3541
WAR EAGLE VEIN
CENTRE STAR No 1 TUNNEL
El 3517
CENTRE STAR MAIN VEIN
Belt of Dikes
9th LEVEL
Fault (L) Dip Vertical
Fault (M) Dip Vertical
Fault (K)
Fault (Q) Av Dip 80°
Fault (R) Av Dip 87°
Fault (T) Av Dip 60°
Fault (J) Av Dip 45°
Fault (M)
Dike Av Dip 70°
Dip of Vein 75°
El 3530
El 3531
El 3593
EAST


ANNIE
JOSIE
LE ROI
BLACK BEAR
300 Ft LEVEL El. 3317
Josie Shaft El. 3786
1350 Level El. 2548
Tramway Dike Av Dip 65°
Fault (A) Av Dip 65° Displ 10 ft
Dip of Vein 65°
Annie Shaft El. 3675
Josie Dike Dip Vertical
Av Strike of Vein
Dip of Le Roi Vein 75°
Fault (E) Av Dip 65° Displ El 3374=5 ft 3059=6
Fault (F) Dip Vertical Displ
Fault (G) Vertical Displ
Dip of Vein 68°
Le Roi Old Shaft
Le Roi Main Shaft El. 3003
Black Bear Tunnel El 3956
Dip of Black Bear Vein 66°
SOUTH


STRUCTURE DETAILS
OF THE
ORE DEPOSITS OF RED MOUNTAIN
ROSSLAND, B. C.
EDMUND B. KIRBY
FEBRUARY 1904
STRUCTURAL GEOLOGY
BY
CARL R. DAVIS E. M.
HUGH ROSE A. B
Scale of Feet
LEGEND
VEINS
FAULTS
DIKES
CENTRE STAR
NICKEL PLATE
LE ROI
LEGAL TENDER
Centre Star Shaft
El 3600
Le Roi Main Shaft
El. 3603
Le Roi Old Shaft
El. 3793
900 Level
350 Ft Level
Fault (K)
Fault (F)
Fault (G)
Fault (H)
Fault (I)
Fault (J)
Fault (L)
SOUTH

MAP No. II.

at a bet
close at
like to l
Mr
McConn
regard
Mr. Ki
of the p
of the l
conclud
depositi
the con
by ther
by the e
Clarenc
suit. I
resemb
land de
origin
retort
posits,
aqueou
Pr
as I ha
have p
tinguis
in the
entirel
the co
of igr
partly
that o
the ro
enclos
dikes,
that h
if the

at a better smelting rate than can be obtained from the smelters close at hand, and this should help both districts. We would all like to hear from Mr. Brock in discussion of the paper.

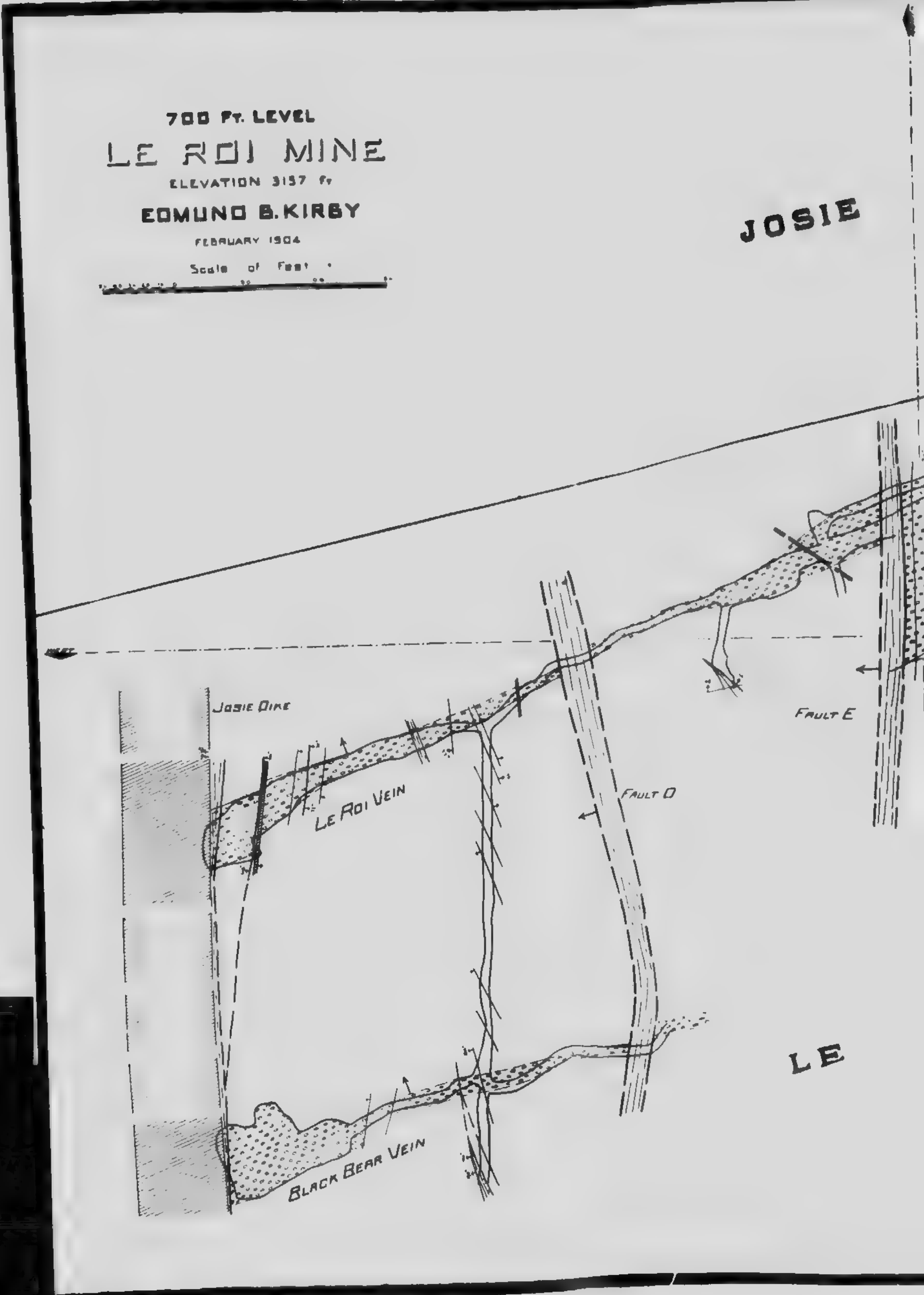
Mr. Brock—Regarding the formation of these deposits, Mr. McConnell, who made the first examination, was inclined to regard these as having been formed in the manner outlined by Mr. Kirby. He reviewed various possibilities, particularly that of the pyrite and chalcopyrite having been formed by segregation of the basic materials around the edge of this gabbro mass, but concluded that the weight of evidence was in favor of aqueous deposition. In a paper which I read before this Institute in 1899 the conviction was expressed that they were undoubtedly formed by thermal solutions, and this theory was afterwards supported by the evidence of the well-known American authorities, Lindgren, Clarence King and Emmons in the Centre Star-Iron Mask law-suit. It was suggested by some that on account of the marked resemblance between the Rossland and Sudbury ores the Rossland deposits should be re-examined in the light of their possible origin by magnetic differentiation in basic eruptive rocks. Our retort was that it would be well to re-examine the Sudbury deposits, keeping in view the possibility of their origin through aqueous concentration and deposition.

Prof. Coleman—I have been much interested in the paper as I have just been at work on the Sudbury region myself, and have picked up many a hand specimen which you could not distinguish from the ores of Rossland. I was especially interested in the final conclusion that the Rossland ores are apparently entirely of aqueous origin and not igneous, since I have come to the conclusion that the large marginal deposits at Sudbury are of igneous origin, though we have there also deposits of ore partly igneous and partly aqueous; but the great deposits, like that of the Creighton mine, are without doubt igneous. We find the rock often entirely enclosed in the ore, and also ore completely enclosed in the rock. The peculiar geological features, such as dikes, are largely absent in the Sudbury region, and it is possible that has a great deal to do with it. I should not be surprised if the fact that there has been a great deal of faulting and shatter-

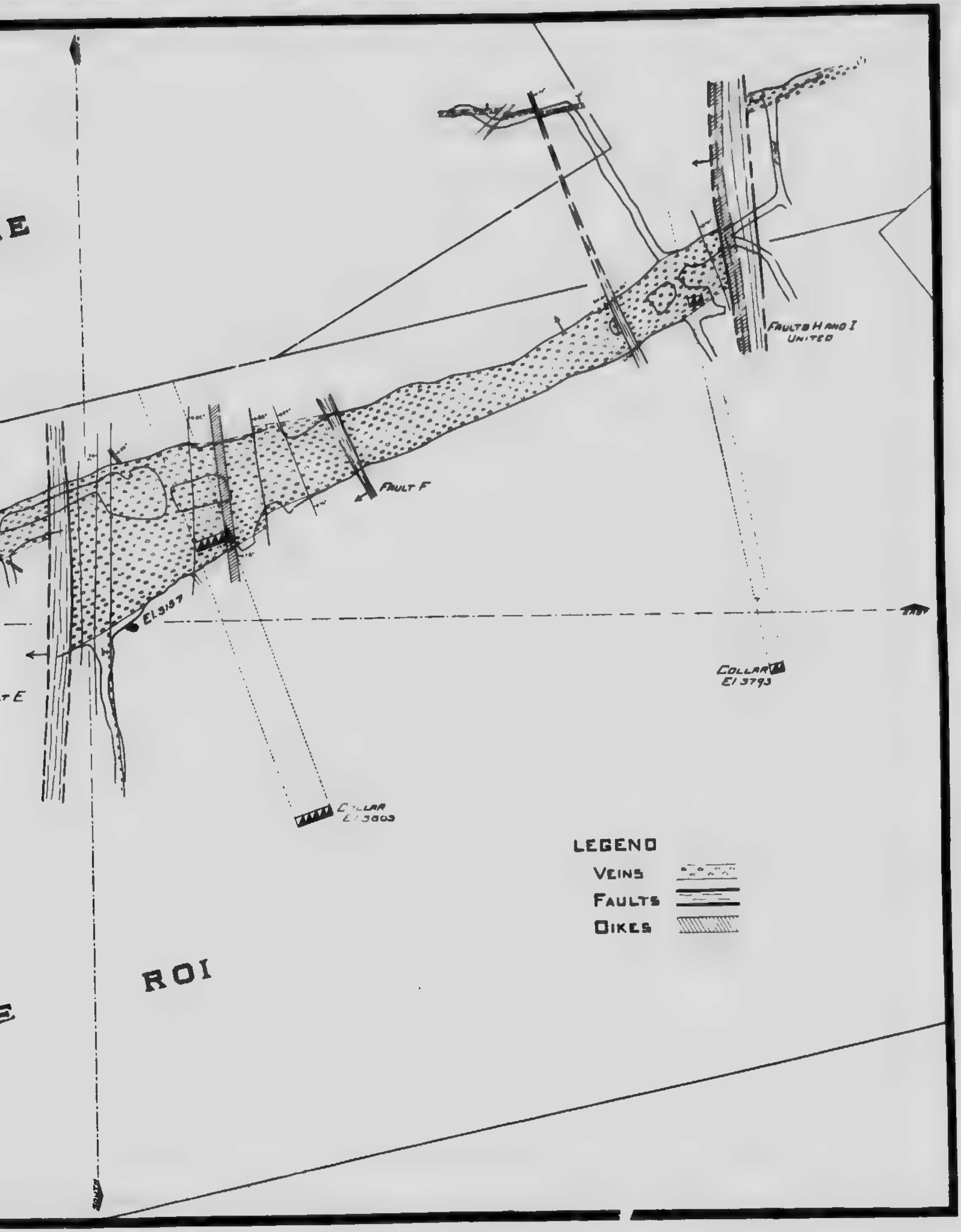
ing in connection with the dikes of different ages may account for some of the secondary re-arrangement, but I think it very possible that some of the pyrrhotite at least may have been part of the magma in the Sudbury region. We find the pyrrhotite existing in several different associations; part of it actually belonging to the rock, and other parts that have clearly been deposited in a secondary way. No platinum has yet been found at Rossland, however. We have the gold and the silver also, of course, in the Sudbury region, though in small amounts.

MR. BROCK—So far as I know no platinum has been found in the ore of the Rossland region, but I do not know that it has been specially sought for. It ought to be. It occurs in the Sudbury ore and in somewhat similar ores in Wyoming.

I think there is no question whatever about the aqueous origin of the pyrrhotite in the Rossland district and in the country immediately to the west. In fact, just to the west, in the Sophie mountain conglomerate, there are deposits formed by replacement of the materials of the conglomerate. I do think, however, that these ore deposits are closely connected with ore of the Alkali syenites found en masse immediately west or northwest of Rossland, and the numerous dikes in Rossland itself There are some points of resemblance between the Rossland deposits and those of Boundary Creek spoken of in Mr. Keffer's paper. Some of the latter consist of masses of pyrrhotite bearing some chalcopyrite, although the majority have magnetite, the oxide of iron, in place of phyrrhotite, the sulphide of iron. These Boundary deposits possess the characters of deposits formed by pneumatolitic contact action. The gases, vapors or possibly solutions from the igneous magma have found their way into the neighboring country rocks near the contacts and there produced these ore bodies. As the solutions, etc., from the igneous magma wandered farther and farther into the country rock the veins would assume more and more the character of ordinary fissure veins. From this type of contact deposit to ordinary fissure vein there may be, therefore, all stages of transition. The Rossland deposits would seem to belong to this series, somewhat similar to the Boundary deposits, but lying much nearer the ordinary fissure vein type.



700 Ft. LEVEL
LE ROI MINE
ELEVATION 3157 Ft
EDMUND B. KIRBY
FEBRUARY 1904
Scale of Feet
JOSIE
Josie Dike
Le Roi Vein
Fault D
Fault E
Black Bear Vein
LE


FAULTS H AND I UNITED
FAULT F
El 3157
COLLAR
El 3793
COLLAR
El 3803
LEGEND
VEINS
FAULTS
DIKES
ROI

MAP Nº III

MR. THOMPSON—Coming from Rossland as I do, I am exceedingly interested in this paper of Mr. Kirby's, and having five years' practical experience in these particular mines, I may say that I think Mr. Kirby is to be complimented on his paper this year; he certainly is to be complimented from the British Columbia miners' standpoint. We nave for years been trying to get a map together showing the geology of the entire Red mountain district, where Mr. Kirby has been doing his work. Mr. Kirby is simply dealing with the mines of Red mountain alone, and it is quite true that on the ground covered by Mr. Kirby the pyrrhotite is very low. From the fact that five thousand tons of ore were shipped last year out of the Kootenay claims, the average value extracted being eleven dollars in gold, I have every reason to believe that the same conditions continue in a westerly direction until the Centre Star dike is found. At a point two thousand feet east of the right hand side of the map exhibited is the Centre Star dike. West we have what is referred to as the Josie dike, so that between the Centre Star and the Josie dike we have veins lying approximately easterly and westerly. In an easterly direction from the Center Star dike we have several mines open. At the extreme east end of the deposits lies what is known as the Columbia Kootenay groups, that contain pyrrhotite ore which they are selling to the smelters, and for which they are being paid for the gold only. The average of last year's shipment for three months was five thousand tons, which amounted to something like eleven dollars per ton. Mr. Kirby is apparently not well acquainted with the district east of his own ground, while I have had the pleasure of being connected with nearly every mine in Rossland except the War Eagle and Centre Star, so that I am particularly familiar with the ground east and west of what is indicated on this map. You will observe on the map the main vein, there are at least four parallel veins crossing the mountain known as Red mountain, one of which is south of the main vein, one immediately north and another which evidently starts from the War Eagle vein, which is a spur vein running practically northwest from the main vein. At this point on the map we have a parallel vein mined by the Le Roi No. 2. The Le Roi No. 2 is a mine

which has recently come to the front a great deal, and as a matter of fact it is the only mine in Rossland that has paid dividends for three successive years. The dividend this year is small but the earnings have been half a million dollars net from that mine during the past three years. You will notice here on the map the Josie dike, which plays such an important part in the ore deposit at Rossland. You can trace it through No. 1 across the mountain until it joins the Centre Star dike a mile and a half away. The Poor Man dike is a spur from the main Josie dike. Ore has been found west of this dike on the Josie and Annie ground, and that is the property they are now depending on to make money out of Le Roi No. 2. During the time I was manager of Le Rio No. 2 we paid three hundred thousand dollars in dividends, and these dividends came largely from ore bodies west of the Josie dike. The White Bear Company, which are operating west of the Josie dike have commenced to build a concentrator and to make shipments from ore discovered west of the Josie dike. Some very valuable ore bodies indeed have been discovered, and how far west they go is still to be determined.

I quite agree with Mr. Kirby in his conclusion, and I can only reiterate my opinion that so far as Rossland is concerned—and I think I may say the same for the whole of British Columbia—we are very deeply indebted to Mr. Kirby for the painstaking manner in which he has treated this subject in the paper which he has prepared. It was a very difficult undertaking for him, and I know Mr. Kirby gave a great deal of time to it, and a great deal more care than I would have cared to give myself. I hope that the government will take the hint, and note that these suggestions are really very valuable for the mining men of our particular district, and that they will be able to publish similar plans at the expense of the government, rather than at the expense of the individual, in the near future.

Mr. Brock—I am very glad that Mr. Thompson called attention to the fact that ore is being mined west of the Josie dike, as it corrects an impression which I did not intend to convey by my remarks in reading Mr. Kirby's paper. I did not mean to say that no ore had been found west of the Josie dike, as, of

course, it has been known all along to occur there; what I meant was that the Le Roi vein, which is cut off by the dike, had as yet not been recognized as such on the west side of the Josie dike, nor was it known definitely in which direction it had been faulted.

DR. BARLOW.—I have listened to the reading of Mr. Kirby's paper with a great deal of attention, especially to that portion of it relating to the origin of the pyrrhotite of the Rossland district in British Columbia. When the phenomenon known as magmatic differentiation was first brought forward to explain the manner of concentration of the deposits of the Sudbury district it was perhaps emphasized too strongly as in itself giving an adequate explanation of all the phenomena witnessed in regard to the mode of occurrence of these ore bodies. More recent and detailed examinations have shown that while the hypothesis of a segregation of these sulphides direct from the magma is in the main the true explanation of the formation of these ore bodies, other agencies, which are usually grouped together under the name of secondary action, have contributed rather largely to bring about their unusual dimensions. Their manner of formation is therefore much more complex than was at first supposed, but the simple doctrine of the direct igneous origin of these ore bodies and their intimate relationship in this respect to certain bands of norite and greenstone served an excellent purpose in directing and controlling all the earlier prospecting work.

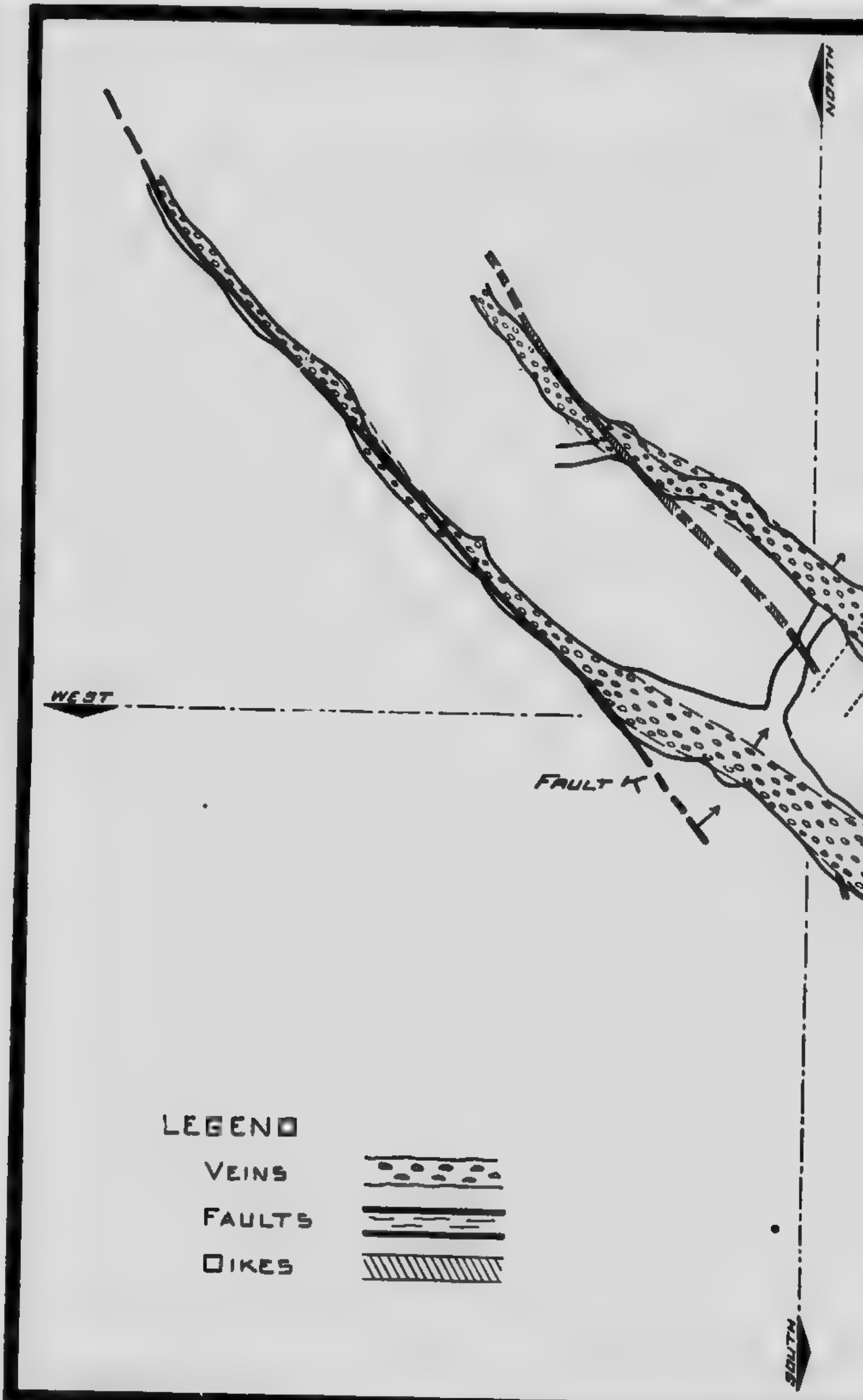
The trend of some of the more recent examinations, however, seems to ignore the full significance of this intimate genetic connection, and argue that secondary causes or replacement are alone and directly responsible for the present position and dimensions of these deposits.

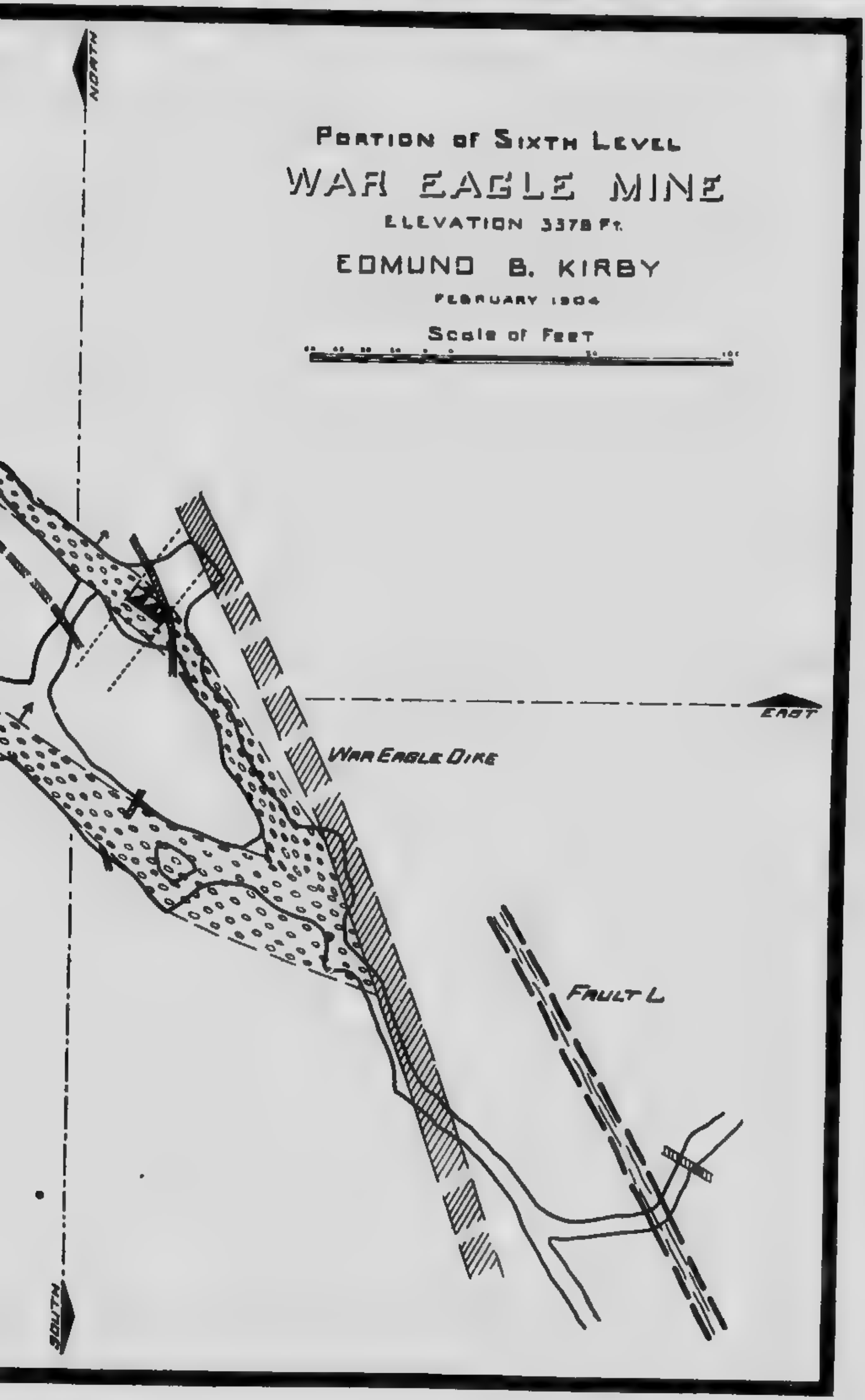
It is, however, certain that the sulphide material was introduced simultaneously and as an integral portion of the same magma along with the other minerals of which the norite or hypersthene-grabbro is composed. The pyrrhotite and charcopyrite are very intimately associated and often intergrown with one another and both are among the earliest of the constituents to crystallize from the original magma, sometimes even antedating the iron ore in which they are occasionally completely enclosed.

They occur in very much the same way as the iron ore, embedded in, or in the immediate vicinity of, the various colored constituents and these two opaque consituents can only be distinguished from one another by their color in reflected light. These sulphides are frequently contained in portions of the norite, which are so fresh as to permit of the positive identification of such unstable compounds as hypersthene, enstatite, diallage and in one case (Little Stobie Mine) olivine, while the plagioclase is always more than normally fresh. Sometimes these sulphides are so abundant in these unaltered phases of the norite as to characterize this rock as a pyrrhotite-norite, specimens having been obtained which contain from 5 to 10 per cent. of these nickel-copper ores. These unusually rich nickel and copper sulphides are invariably associated with the norite and all of those of economic importance are situated either directly on the line of junction between this and the associated rocks or in its immediate neighborhood.

The question of the origin of these ore bodies is intimately connected with those processes, as yet but imperfectly understood, attending the various stages of the cooling and differentiation of huge bodies of igneous magma. As is doubtless well known to all of you, there is no such thing as dry fusion in nature and all igneous action is attended with or immediately followed by more or less pronounced vein or pneumatolytic action and certain rock masses and occurrences of mineral are representative of the various transitions between what may be termed hydro-igneous fusion to igneo-aqueous solution.

There can be little doubt of the abundant presence of such heated solutions which are capable of dissolving out and under certain conditions of redepositing these sulphides. Such agencies began their work before the whole magma had cooled, bearing their heavy burdens of sulphide material, most of which was obtained from the magma in the immediate vicinity, to occupy the various cavities and fissures as fast as these were formed. The whole of this action was practically completed before the intrusion of the later dikes of the olivine diabase, which are now regarded as the end products of the vulcanism to which the norite masses owe their eruption. In certain of the deposits, hydro-


NORTH
WEST
FAULT K
SOUTH
LEGEND
VEINS
FAULTS
DIKES



PORTION OF SIXTH LEVEL
WAR EAGLE MINE
ELEVATION 3378 Ft.
EDMUND B. KIRBY
FEBRUARY 1904
Scale of Feet
NORTH
EAST
SOUTH
WAR EAGLE DIKE
FAULT L

MAP Nº IV

cher
Vict
of tl
man
deve

bein
alte
Seco
calc
ciat
in tl
igne
deve

a m
add
of n
up
rock
The
outl
with
asso
four
depo
tent

ly, t
mag
diffe
mix
each
mat
with
we
yet

chemical agencies have been more active than in others, as at the Victoria Mine and some of the Copper Cliff mines, but in the case of the Creighton Mine, magmatic differentiation has, as Dr. Coleman remarks, been the main factor determining and favoring the development of this the largest nickel mine in the world.

The Rossland, B.C., ore bodies are likewise of igneous origin being associated with a monzonite, but the rock is very much more altered both as the result of dynamic and hydrochemical action. Secondary action is very much more pronounced and quartz and calcite, which are comparatively rare in the Sudbury rocks associated with the ore bodies, are both very abundantly represented in the Rossland district. In the case of the Rossland ore bodies, igneo-aqueous solution has played the most important part in their development.

After all, however, the origin of these ore deposits is largely a matter of theory and opinion, and strong arguments may be adduced to support the view either that they are the direct result of magmatic segregation or that the sulphides have been brought up from considerable depths to replace certain portions of the rock or fill up fissures and diorites caused by structural weaknesses. The real practical side of geological investigation consists in the outlining of these immense bodies of intrusive norite or gabbro with which the nickel and copper deposits of Sudbury are always associated, for although pyrrhotite and chalcopyrite are both found in connection with the older green schists and diorites, the deposits of these minerals in such cases are neither of large extent nor of unusual richness.

Mr. Ingall—I am glad the point was brought out so strongly, that the difference between the gentlemen who are so fond of magmatic differentiation and the other theory is after all only a difference (or differentiation) of terms. These magma are a mixture of a lot of materials in various stages of separation from each other and the question of the actual temperature is not a matter of much practical importance, as when dealing with temperatures we may vary from something which we now think very cold to something we think very hot, and yet the real difference may be small. I remember when I was

studying the Lake Superior silver district for the Survey in 1886, in one of the drifts in the Rabbit Mountain mine the vein was filled with a pulp thick enough to float a lot of crystals of the other minerals that formed in these veins, such as zinc blende and galena. The pulp was thick enough to hold them up, and it accounted in an interesting way for the fact that you find these perfectly formed crystals in such places. I should like to know whether that should be called magmatic differentiation or vein action. The degree of heat which constitutes the magma has never been settled.

PROF. MICKLE—With regard to the comparison between the Rossland and the Sudbury deposits I cannot see any resemblance at all. The first thing that must strike anyone is the remarkable difference in the form of the deposits, a plan of the Rossland ore bodies would have the form of a river, whereas the Sudbury deposits have the form of lakes, with or without irregular bays. Moreover, in Sudbury the plan of any particular level may differ entirely from that of the level above and below. Another difference that is striking is that the country rock in the Rossland district is weathered to a considerable distance back from the vein. In 1896 I took a systematic set of samples of rock from the Centre Star vein at Rossland, in a place where there was a cross-cut that ran a hundred feet or so in each direction, starting close to the vein and going back twenty feet or more in each direction. The samples that I brought back were kindly examined by Dr. Coleman; without knowing where they were from he was able to notice the variation beginning with rock within a few inches of the vein that was so far decomposed that it was unrecognizable, back to the rock over 20 feet from the ore that was almost unweathered. The degree of weathering was in proportion to the distance from the vein, showing clearly that there was an action proceeding from the vein outwards, which, I think, could only be due to heated solutions. Moreover, in Rossland you see running across the ore veinlets filled with calcite, whereas you never see that in Sudbury. On the other hand in the latter place pieces of rock are seen imbedded in the ore, the sizes varying from the very smallest particles up to pieces presenting a face of several hundred square

feet in area. Another respect in which they differ greatly, which affects their practical working and which, I think, points to their origin, is the distribution of their metallic contents—in Sudbury there is the greatest uniformity, relatively speaking, that is, taking the pyrrhotite only in any given deposit it will be found that the percentage of nickel and also platinum remains very nearly constant throughout the deposit, variations in the percentage in the ore are caused by inclusion of more or less rock. It is true that the amounts of copper vary considerably in different parts of the same deposit, as pointed out by Mr. David H. Browne in his paper on "Segregation in Ores and Mattes," there is a difference of 7 per cent. or more in the analyses of copper and nickel in different parts of a matte cooled in an ordinary matte pot. With regard to the distribution of the metals in the Sudbury deposits the ore resembles a low grade matte. In Rossland, on the other hand, the chief metal value—the gold—is most distressingly erratic, many large pyrrhotite deposits in the Rossland district contain no gold as far as worked, and others have gold only in places. This irregular distribution of the gold in itself appears to exclude the possibility of the igneous origin of the Rossland deposits.

Referring to the possibility of nickel in the Rossland pyrrhotites mentioned by Mr. Brock, in the early days of Rossland, when a great many more claims were being worked than at present, frequent analyses were made for nickel. I believe it was only found in any quantity worth considering in one place, viz., the Georgia claim, towards the Kootenay mountain. Any nickel occurring in ores from shipping mines would have, of course, long since been detected in the matte on smelting.

The President—We have had a very interesting paper, and I think that Professor Brock is to be congratulated for reading it in such an able manner at such a short notice. I want to join Mr. Thompson in congratulating Mr. Kirby on the excellence of his paper, the care with which he has prepared the maps, and the valuable information which he has placed at our disposal. This paper will be a very important contribution to our transactions. I was very much interested not only in the paper, but in the discussion which followed, and which supplied a great deal of instructive

material. As Mr. Kirby holds in the paper, and Professor Mickle has further pointed out, there is a very great difference between the veins of evidently aqueous deposition in Rossland as referred to in the paper, and the occurrences of similar ores at Sudbury, but nevertheless one may trace, as Dr. Barlow pointed out, the continuation of the igneous phenomena all through, from the magma itself, as at Sudbury, without hardly anything but the segregation of different mineral masses, to fumarolitic gas and aqueous depositions as at Rossland, that effects away form the magma itself, through the fissures of disturbed broken and shattered country rocks, in more or less close proximity to the parent igneous magma however. The one act of igneous or volcanic phenomena which is the final cause of the existence of these ores at both places, can be traced right through in a very instructive way, notwithstanding the very great difference between the physical nature of the deposits, and that is a very interesting thing, showing that when we come to regions like Sudbury we have reached pretty well to the bottom and final source. The great uniformity which Professor Mickle has pointed out of the mineral constituents in these Sudbury ore masses more directly from the magma is, therefore, only natural. There is also the other fact pointed out by Professor Coleman that there are no dikes at Sudbury, while Mr. Kirby's map of the Rossland region is full of them. That fact that there are no dikes at Sudbury is one of the great proofs that we have there the segregation at the commencement of the igneous phenomena. I would like to hear something from Mr. Thompson about the concentration of the low grade ores of that district, if he would care to deal with that phase of the question.

MR. THOMPSON—The concentration of low grade ores is rather a big subject. The methods adopted are the usual division to a suitable mesh and trying to get as clean a concentrate as possible. The Le Roi No. 2 sends the tailings to be treated by the Elmore process. Technically the plant has been a success, but commercially there is apparently room for improvement. The mill is a small one, the plant is experimental and I rather fancy that when larger units are put in, that probably the cost will be materially reduced. The general manager of the Con-

centration Syndicate in a report to his London directors states that it will cost four dollars a ton after the ore is mined, with the present plant, but I think that this will be reduced to two dollars. Our friend, Mr. Kirby, is building a two hundred ton smelter at Trail to treat the War Eagle and Centre Star ore. He has not yet published his method of concentration so far as I can ascertain. The White Bear Mining Company, of Rossland, have ordered a one hundred ton Elmore plant for the treatment of its copper ores. If the cost is reduced sufficiently low I am quite satisfied that the plant will be a great success.

I have done a great deal of work on pyrrhotite ores with a view of cyaniding them rather than sending them to the smelters. At present we sell to the smelters. Whether we can go on with our smelter shipments or not depends on the question as to whether we can dispose of our ore at the present rate to the smelters. We can send the low grade ore at present to the smelter on favorable terms and make money out of it.

A year from now probably the members of this Institute will be able to get more valuable data as to the actual operation than they are in a position to get at the present time. At the present time everything is of an experimental nature, but I am quite satisfied that Mr. Kirby's process must have been quite satisfactory to him. He is a very conservative mine manager indeed, and I would hardly think that he would enter on a process of concentration unless he had fully concluded it would be successful. He is spending a great deal of money on one of the finest concentrating plants in the country, and it is only a matter of time with him when I believe he will make it a success. Of course, I may be considered optimistic, but I do think that the turn has come as far as the Rossland camp is concerned, and that many of the properties which in the east are now considered of no value, will become paying properties as these obstacles are soon to be removed which have prevented success in the past.

THE PRESIDENT—I wish to express the thanks of the Institute to Mr. Thompson, and I hope that his anticipations will be realized. I have no doubt that we can rely upon such men as Mr. Elmore, Mr. Kirby and others who are tackling this difficult problem, to attain a high measure of success.